SUPPORTING INFORMATION

Ultra-thin $AlPO_4$ Layer Coated $LiNi_{0.7}Co_{0.15}Mn_{0.15}O_2$ Cathodes with Enhanced High-Voltage and High-Temperature Performance for Lithium-Ion Half/Full Batteries

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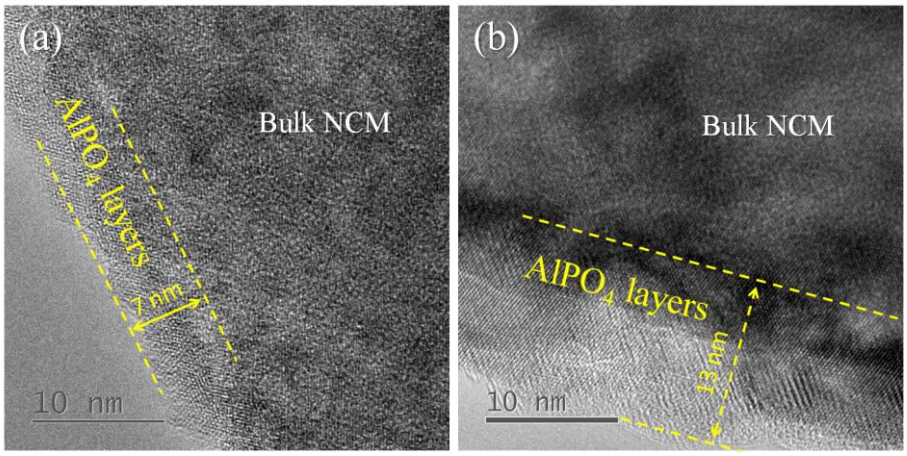

FIGURE S1 | HRTEM images of AP-NCM materials with different coating thicknesses: (a) ~7 nm and (b) ~13 nm. Based on a large number of TEM images, the average thickness of the coating layers on AP-NCM particles is ~10 nm. The lattice fringes in the (a and b) can be matched with $AlPO_4$ structures (JCPDS #31-0028).

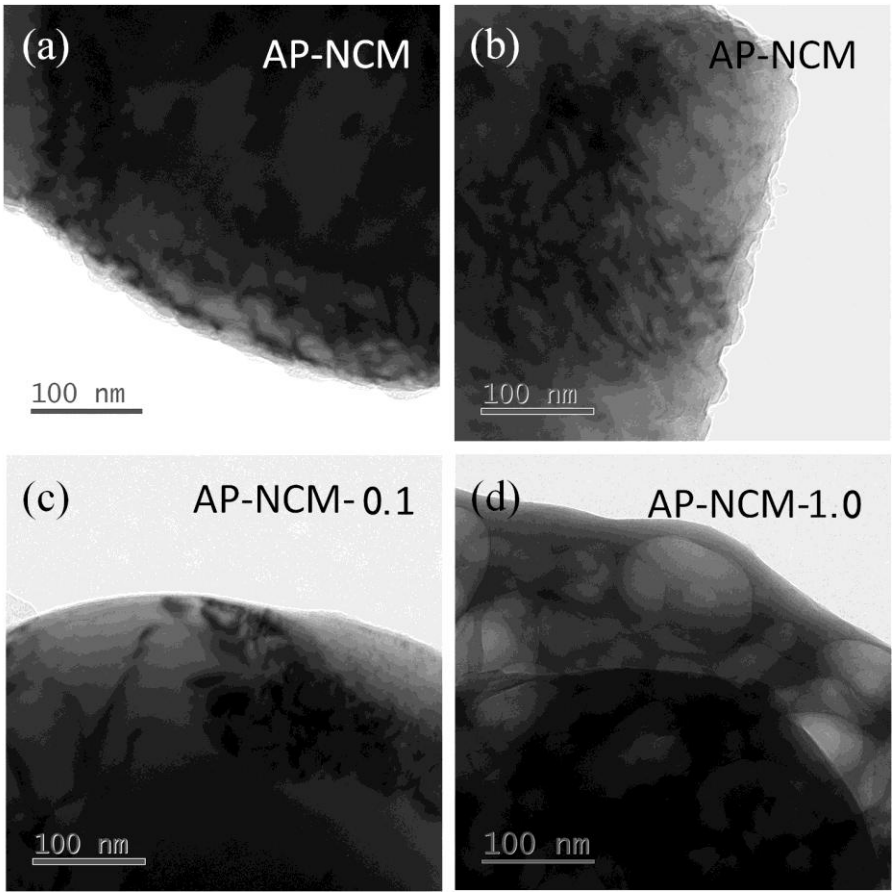

FIGURE S2 | Typical TEM images of three coated NCM samples with different surface $AlPO_4$ amounts: (a, b) AP-NCM with 0.5 wt%, (c) AP-NCM-0.1 with 0.1 wt%, (d) AP-NCM-1.0 with 1.0 wt%. For sample AP-NCM-1.0, many particles are surface clean and no obvious coatings can be found. However, coating layers with various thickness are existed in sample AP-NCM-1.0.

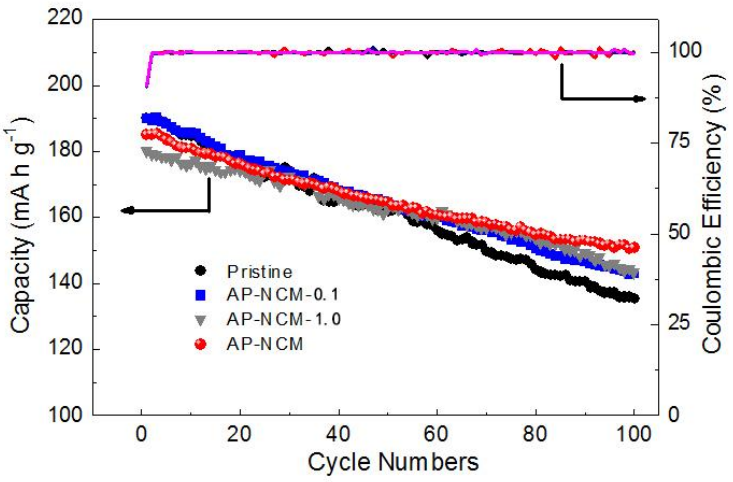

FIGURE S3 | Cycle performance of $AlPO_4$ coated samples with different contents.

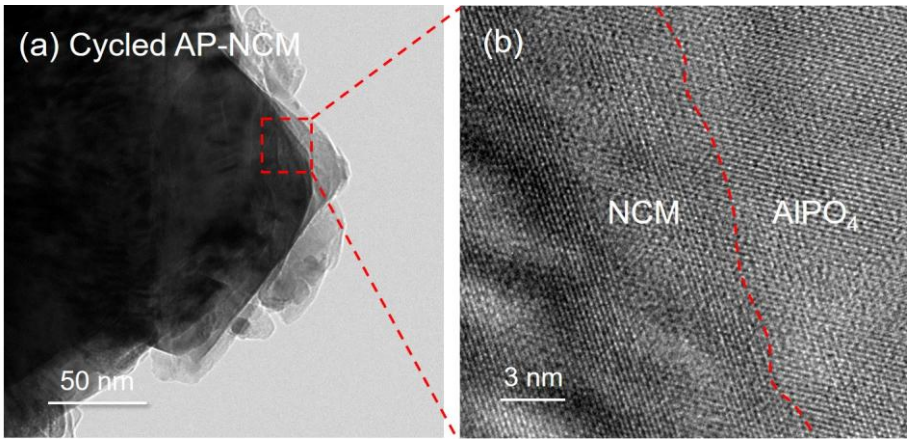

FIGURE S4 | TEM and HRTEM images of a particle surface of the cycled AP-NCM electrode. Here, the AP-NCM electrode is cycled between 3.0−4.5 V at 1C for 100 cycles (25 °C).

TABLE S1 | Comparison of the 25 °C cycling performance of previously reported Ni-rich NCM cathodes with results in this work.

Samples	Voltage range (V)	0.1C capacity (mA h g^{-1}) / Initial coulombic efficiency	Capacity retention / cycles / rate	Ref.
$LiNi_{0.7}Co_{0.15}Mn_{0.15}O_2$	3.0-4.5	200.2 / 89.14%	71.4% / 100 / 1C	This work
$AlPO_4$@ $LiNi_{0.7}Co_{0.15}Mn_{0.15}O_2$	3.0-4.5	195.7 / 89.07%	81.5% / 100/ 1C	This work
$LiNi_{0.5}Co_{0.2}Mn_{0.3}O_2$	3.0-4.3	156.0 / 85.7%	91.2 % / 100 / 1C	Zeng et al., 2019
$LiNi_{0.5}Co_{0.2}Mn_{0.3}O_2$	3.0-4.4	171.0 / 85.2%	74.0 % / 100 / 1C	Zeng et al., 2019
$LiNi_{0.5}Co_{0.2}Mn_{0.3}O_2$	3.0-4.5	180.0 / 84.3%	67.8 % / 100 / 1C	Zeng et al., 2019
Li_3PO_4-$AlPO_4$-$Al(PO_3)_3$@ $LiNi_{0.8}Co_{0.1}Mn_{0.1}O_2$	3.0-4.3	201.8 (30 °C) /-	85.4% / 50 / 0.5C	Feng et al., 2019
$AlPO_4$@ $LiNi_{0.8}Co_{0.2}O_2$	3.0-4.35	170.8 (rate: 150mAh/g) /-	89.1% / 60 / rate: 150mAh/g	Hu et al., 2008
$LiNi_{0.8}Co_{0.1}Mn_{0.1}O_2$	2.7-4.5	203.0 (0.2C) / 80.9%	64.0% /100 / 0.5C	Zheng et al., 2015
$LiNi_{0.72}Co_{0.10}Mn_{0.18}O_2$	2.7-4.5	196.0 (0.2C) / 83.9%	85.7% / 100 / 0.5C	Zheng et al., 2015
$LiNi_{0.8}Co_{0.15}Al_{0.05}O_2$	2.8-4.5	202.83 / 89%	55.3% / 100/ 1C	Dai et al., 2016
Al_2O_3@$LiNi_{0.8}Co_{0.15}Al_{0.05}O_2$	2.8-4.5	184.70 / 90%	71.7 % / 100/ 1C	Dai et al., 2016
LiV_2O_4@$LiNi_{0.5}Co_{0.2}Mn_{0.3}O_2$	3.0-4.5	189.5 / 82.6%	80.0% / 100 / 1C	Lu et al., 2019
PANI@ $LiNi_{0.8}Co_{0.1}Mn_{0.1}O_2$	3.0-4.3	185.0 / 91.1%	80.1% / 100 / 0.1C	Gan et al., 2019
$LiNi_{0.8}Co_{0.1}Mn_{0.1}O_2$	3.0-4.3	175.0 / 81.2%	85.3% / 100 / 1C	Tang et al., 2019
$LiAlO_2$@ $LiNi_{0.8}Co_{0.1}Mn_{0.1}O_2$	3.0-4.3	186.4 / 85.6%	89.0% / 100 / 1C	Tang et al., 2019
$LiAlO_2$-Al_2O_3@$LiNi_{0.8}Co_{0.1}Mn_{0.1}O_2$	3.0-4.3	190.5 / 83.6%	96.8% / 60 / 1C	Feng et al., 2019
Al-doped $LiNi_{0.7}Co_{0.15}Mn_{0.15}O_2$	3.0-4.5	214.8 / 93.3%	94.3% / 200 / 0.5C	Feng et al., 2019
$LiYO_2$@ $LiNi_{0.8}Co_{0.1}Mn_{0.1}O_2$	2.8-4.5	189.4 / 81.4%	98.4% / 100 / 1C	Zhang et al., 2019
$LiNi_{0.5}Co_{0.2}Mn_{0.3}O_2$	2.8-4.5	173.2 (1C) / 80.0%	66.0% / 50 /1C	Wang et al., 2019
SiO_2@$LiNi_{0.5}Co_{0.2}Mn_{0.3}O_2$	2.8-4.5	166.0 (1C) / 82.0%	92.4% / 50 /1C	Wang et al., 2019